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Terranes older than those of Paleozoic age occupy in Iowa a very small area. Attention which has been bestowed upon them is about commensurate with their relative surface extent. Heretofore, little attempt has been made to determine their broader stratigraphic relationships, their real position in the general geological column, their possible subdivision, or their role in the geotectonics of the region. It has seemed all sufficient to merely note their existence in the extreme northwest corner of the state. Yet, these very rocks now appear to have a history longer, more complicated and more vicissitudinous than any other terrane represented within our borders.

We now learn that some of these Pre-Cambric rocks are very much younger than was thought to be the case; and that others are very much older. For the first time we are able to compare them with a standard section of the most ancient sediments known. The most complete and satisfactory scheme of classification is that adapted from Lawson's scale for the Lake Superior district. Our rocks are really a part of these more northern masses, a long tongue of which extends from Lake Superior southwestward into Iowa and South Dakota. This section of Iowa rocks may be expressed as follows:

PRE-CAMBRIC ROCKS ABOUT THE NORTHWEST CORNER OF IOWA.

		Feet.
	Unconformity.	
8.	Corson diabase	
7.	Hull porphyries	500
6.	Tipton sandstones	450
	Unconformity.	
5.	Splitrock[1] slates	75
4.	Sioux quartzites	500
3.	Jasper conglomerate	30
	Unconformity.	
2.	Gneisses	1,000+
1.	Schists	1,000+

Of these formations Nos. 1 and 2 are assigned to the Azoic; Nos. 3 to 5 to the Animikian series of the Archeozoic; and Nos. 6 to 8 to the Keewenawan series, also of the Archeozoic.

The salient characters of the several formations are briefly enumerated below. The full description and discussion of their broader stratigraphic affinities are necessarily reserved for another occasion.

[1]These are the slates described by S. W. Beyer (Iowa Geol. Surv., Vol. VI, p. 105, 1897).

The gneisses and schists which are reached in several of the deep-borings in northwestern Iowa appear to belong, without much doubt, to the fundamental crystalline complex here designated as Azoic. Their foliated character attests their great antiquity. At Sioux City the drill entered them for a distance of 840 feet.[2] At this point the rock was mainly dark gray in color, and the chief minerals were plagioclase, quartz, and biotite, with some hornblende. In the deep-well at LeMars 500 feet of typical gneiss and schist were penetrated by the drill. Fifty to seventy miles to the northward, in Minnesota, around the headwaters of the Des Moines river, these same rocks crop out and are open to direct inspection.

The Pre-Cambric rocks which outcrop about the extreme northwest corner of the state are commonly covered by the single title of Sioux quartzite. There are, in fact, several distinct members. The formations are identical with those of the Animikian series which is so well developed farther to the northeastward. It seems best to regard the rocks of the Siouan region as belonging here rather than with the original Huronic of Canada to which they are probably not to be traced and with which they bear no direct relations.

A conglomeratic phase of the quartzite appears east of the village of Jasper and south of Pipestone, in Minnesota. This is near the easternmost outcrops of the Sioux formation and it may be a part of a true basal conglomerate. The pebbles are of all sizes up to an inch in diameter. The observed thickness of the Jasper conglomerate is about 20 feet.

The characters of the Sioux quartzite have been repeatedly described in the various volumes of the Iowa Geological Survey. I have already reviewed, in the Proceedings of the Academy[3] opinions as to the age of this terrane; and its various features are elsewhere considered.[4] As lately determined the thickness of this formation is probably not more than 500 feet, instead of thrice this figure as formerly estimated.

Above the quartzite proper, or as the upper part of the section, are red and spotted slates. They are well exposed along the Splitrock creek from Corson northward. Their lamination is not true slaty cleavage but an ordinary stratification effect. At the Palisades, Pipestone, and elsewhere, the lamination is not very apparent. The more massive beds which are sometimes ten feet thick afford the so-called catlinite. The Splitrock slates doubtless have a wide areal extent.

Overlying the Animikian rocks in central Minnesota is a great succession of basic and acidic extrusives and red sandstones. They con-

[2]Iowa Geol. Surv., Vol. XXI, p. 1096, 1912.
[3]Proc. Iowa Acad. Sci., Vol. II, p. 18, 1895.
[4]Iowa Geol. Surv., Vol. I, p. 15, 1893.

stitute the Keewenawan series. An erosional plane of unconformity separates the two series of rocks. The entire sequence is cut by intrusives—diabases, gabbros, and granites. Rocks associated with the Sioux quartzite have identical characters and structural relationships. For all practical purposes they seem to be a part of the typical Keewenawan series.

The red sandstones and slates which often contain enough iron oxide to rank them as low-grade iron ores, have been reached in a number of deep-borings, notably in the well at Tipton. After passing through over 2,000 feet of Paleozoic sediments, 465 feet of the red beds were penetrated. These Tipton sandstones correspond in every way to formations outcropping seventy-five miles to the northward in Minnesota. It is probable that in the Hull well the same beds alternate with the quartz-porphyries. A notable feature of the Keewenawan sandstones is that they are not metamorphosed into quartzites, but are almost indistinguishable from associated sandstones of Cambric age.

The extensive succession of quartz-porphyry sheets disclosed in the deep-well at Hull is of exceptional interest. The drill penetrated over 450 feet of them. Their petrographic characters are fully described by Professor Beyer.[5] These porphyries are not intrusive sills as sometimes considered, but successive lava flows which were poured out upon the surface of the ground during Keewenawan time. The several sheets alternate with sandstones, a fact that points to the lava's solidification under water.

An instructive factor to be taken into account is the circumstance that the lavas appear to occupy an old valley, resting partly upon the ancient gneisses and partly upon the Sioux quartzites. These porphyries are identical with the acidic lavas which once flooded the country to the north far into Canada.

The diabase dike displayed so conspicuously at Corson, South Dakota, is one of many which cut the Pre-Cambric rocks of the Siouan ridge. These dikes vary in width from a fraction of an inch to one or two hundred feet. They traverse the Animikian rocks and therefore are much younger than the latter. In central and north-central Minnesota they do likewise; but in those regions there are no younger rocks covering the Proterozoics.

The geologic age of the diabase dikes, sills and bosses is commonly regarded as Keewenawan, but of this there is no positive evidence. In view of the fact that in the Siouan region there was a notable uplifting in Triassic times it is not beyond possibility that all of the diabases are

[5]Iowa Geol. Surv. Vol. I, p. 163, 1893.

of that age and are to be associated with the forming of the great Siouan Mountain ridge of that time. If it could be found that any of the Paleozoic rocks were fissured by these intrusives the testimony would be conclusive on this point. However, until it is shown by direct observation that the basic dikes actually do cut the overlying Paleozoics the Corson diabases are best regarded as Keewenawan in age.

With the recognition of a diversity of Pre-Cambric rocks about the point where the three states of Iowa, Minnesota and South Dakota meet a wide new field of investigation is opened up in our local geology.

There is another aspect of the Pre-Cambric rocks of Iowa that should not be lost sight of. At this time the special geologic significance of the terranes lies in the circumstance that they have suddenly acquired world-wide interest on account of the fact that they supply critical data for evaluating for the first time the duration of Pre-Cambric periods. They give us a basis of comparison of the mid-continental sections with the Paleozoic successions as we best know them. They enable us to formulate a systematic scheme of Pre-Cambric stratigraphy that is comparable in its variety, its complexity, its detail and extent, with the Post-Cambric standard which has been evolved during the course of the past century.

In this connection, also, the recent determination of the antiquity of the oldest fossil faunas has a direct bearing upon our own rock section. Through a period of more than two generations progress so inappreciable had been made in onerous attempt to carry back farther than Cambric time the geologic record of life on our globe that many students of ancient organisms almost despaired of ever seeing their efforts in this direction rewarded. 'At no stage, however, during these long years had the problem been regarded entirely without hope of solution. Latterly there had been accumulated a great mass of pertinent facts. So suggestive had been found some of them that an eminent English geologist, fully a decade ago, was led to predict, with no little confidence, the final differentiation of the great Pre-Cambric complex into an orderly succession of fossiliferous formations not very unlike that of the familiar Paleozoics. The results of the past year or two have, without warning, more than fulfilled the most sanguine of these expectations.

The wide interest aroused by these recent discoveries of abundant well-preserved organic remains in rocks of undoubted Pre-Cambric, and hence Pre-Paleozoic, age is secondary only to the enthusiasm produced a few months ago by the actual location of the fossiliferous horizons in the general geological column. As definitely determined these oldest

fossil-bearing levels are stratigraphically more than two miles beneath all other known horizons yielding traces of life. These revelations are, of course, as important biologically as geologically. They materially modify all of our previously held views on the subject. They open up a more inviting field of investigation than awaited the paleontologists of the first half of the last century when they started to unravel the life record preceding Cretacic times. They promise even greater triumphs than when the Paleozoics first revealed their secrets to Murchison, Sedgwick and Lonsdale.

In past attempts to discover fossils in strata older than those of Paleozoic age the most serious obstacle always has been the highly altered condition of the ancient rocks whenever they were exposed to view. The well-known geologic law that the older a rock is the more metamorphosed is it likely to be especially applies to the Pre-Cambric formations. It is a criterion of such great weight that it is still a decisive factor in the determination of the relative ages of these old rocks. In the majority of cases known metamorphic processes have gone on so long and so intensely that it is often almost impossible to tell whether a rock-mass was originally igneous or sedimentary in character.

Indeed, as is well known, there is a large school of able investigators and acute thinkers which has reached the conclusion that the crystalline schists are almost wholly of eruptive nature. Among those who have hoped for a different explanation the great endeavor has been to find a locality somewhere in the world where rock-alteration is so slightly developed that the original sedimentary characters, if they ever really existed, are not completely obliterated and where the fossils are still in recognizable shape. A number of just such promising spots in different parts of the world are now known. Upon them much effort is being expended in the attempt to force them to yield up their fossil treasures.

It remained for two widely separated localities in North America, suddenly and almost simultaneously, to disclose the long sought sections. One of these places is in the Lake Superior district, and the other is in the Rocky cordillera of the West. In the first of these localities especially, does it appear that a definite standard of terranal succession of the Pre-Cambric rocks is capable of establishment with a measure of accuracy and detail quite comparable to that of the younger and highly fossiliferous Paleozoic sequence so well known.

Peculiar notions surround the discovery of Pre-Cambric fossils. When it became apparent that there really existed below the lowest Paleozoic horizons—or Olenellus zone—a great sequence of little altered sediments indistinguishable lithologically from the Early Cambric

rocks, there at once arose among some of the workers on these ancient clastics an inordinate desire to repeat the brilliant achievements of the great English geologists seventy-five years previous. In the haste to formulate a theoretical deduction the real significance of many obvious facts was overlooked. An unfortunate misconception which resulted for a score of years retarded rather than advanced further progress.

At the very beginning there was, furthermore, a strong desire at once to evaluate the conclusions. It was argued that the length of time during which these Pre-Cambric sediments were formed was many times greater than that which had elapsed since the commencement of the Paleozoic era. Thus entirely without access to a measurable rock-section, without an adequate scheme of formational sequence, and without the aid of fossils there were made estimates of the duration of time required for the accumulation of the Pre-Cambric sedimentaries. These figures have crept into many of the more recent text-books. In a measure the results were unconscientiously forced until the period became excessively long. After making liberal allowances for frequently mistaking slaty cleavage for bedding planes, for personal equation, and for the wrong interpretation of sequence, there was still a very large factor of wholly unreliable data to be taken into account.

In the absence of any known fossils in the Pre-Cambric rocks strong appeal is ordinarily made to the possibilities which modern biologic or embryologic teachings point out. The fact that at the beginning of Paleozoic time, as we now understand conditions, life suddenly and profusely burst forth along all its main zoological groups is taken to indicate, notably by Professor Van Hise, that at this period it was already more than nine-tenths differentiated, the inference being that the oldest Cambric fauna is only a little way back in an immeasurable life-span. So far as this opinion rests upon the diversity of types in Cambric times it has no good basis. As W. K. Brooks so well shows "Evolution of the ancestral stems must have taken place at the surface of the sea, and all the conditions necessary for the rapid production of types were present when the bottom fauna first became established."

It is, then, on the continental shelves and in the epi-continental seas, belts or areas with which paleontologists have mainly to deal, that owing to hardships imposed and to the fierce struggle for existence among the simpler types of life, diversity of form and structure is ever present and exceedingly rapid in development. Especially bearing upon this phase of the problem are the observations of A. Agassiz on the bathymetric distribution of modern echinoids in the Gulf of Mexico. As one passes from the shore into deeper and deeper water the forms take

on successively Pliocene, Miocene and Eocene characters until those of the deepest zone persist with well defined Cretacic features.

Notwithstanding the fact that in the oldest Cambric faunas we have essentially the characteristic forms of the primitive life of the sea-bottom, and that we need not expect anything so very different from these bottom-forms in the oldest rocks which may ever become accessible to us, it is instructive to know of what the most ancient fauna recently discovered in Pre-Cambric beds consists, and **where it actually belongs** in the general geologic time-scale. In these most ancient fossil faunas we may not, therefore, anticipate any very new or very remarkable ancestral or previously unknown stems.

To the bottom of the general geologic column as usually presented in the text-books of the science we may now add the following scheme of fossiliferous formations, remembering that each eral division represents a time-span equal to or even surpassing in duration that covered by the entire Paleozoic succession, and even the entire time interval which has elapsed since the laying down of the earliest Paleozoic sediments.

TENTATIVE TAXONOMY OF PRE-CAMBRIAN ROCKS OF LAKE SUPERIOR.

Eras	Periods.	Sub-periods.	Series.	Rocks.
PALEOZOIC	CAMBRIC	Late Mid Early	*Ozarkian* *Croixan* Wanting	Limestones Sandstones Unconformity
PROTEROZOIC	SUPERIORIC	Late Mid Early	*Keewenawan* Interval *Animikian*	Lavas Unconformity Slates
	SELKIRKIC	Late Mid Early	Interval	Sediments 20,000 feet thick in Cordillera
	ANIANIC	Late Mid Early	Interval	Unconformity
ARCHEOZOIC	ALGOMIC	Late Mid Early	Unnamed Interval *Soultan*	Lavas, granites Unconformity Quartzites
	HURONIC	Late Mid Early	Unnamed Interval *Marquettan*	Lavas? Unconformity Limestones, etc.
	LAURENCIC	Late Mid Early	Unnamed Interval *Keewatin*	Lavas, Granites Unconformity Lavas, slates
	VARENNESIC	Late Mid Early	Unnamed Interval *Coutchichingan*	Lavas? Unconformity Slates
AZOIC				Slates Gneisses Schists

The great triumph of Murchison and Sedgwick in the first half of the last century in bringing order out of chaos in the case of the vast Transition mass of rocks and in working out two great systems according to the fossils contained seems destined in the opening decades of the new century to be more than matched by the differentiation of two huge sequences of fossiliferous terranes each of greater stratigraphic and taxonomic importance than that of the entire Paleozoic succession as now known.

DES MOINES.